Stable Isotopic Studies at the TAN Site of INEEL, Central Idaho

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RESEARCH OBJECTIVES

The purpose of this project was to explore and refine applications of isotope measurements for guiding environmental remediation strategies. The isotopic compositions of samples from field sites were analyzed to address both basic scientific issues and site-specific problems. Initial efforts were concentrated on two sites at the Idaho National Engineering and Environmental Laboratory (INEEL). During the final year of the project, the focus of work was shifted to the Hanford site in Washington. This contribution summarizes the results of work done on the TAN (Test Area North) Site in Idaho, a 2 km-long plume of mixed wastes containing low-level radionuclides, sewage and chlorinated solvents that were injected into the groundwater between 1955 and 1972.

Our first objective was to determine the primary factors affecting regional groundwater flow at the TAN site. The direction of groundwater flow in the Snake River Aquifer is generally from northeast to southwest, but at the TAN site, groundwater flows eastward, then southeastward. The second objective was to evaluate the evidence for natural degradation of trichloroethene (TCE) in the TAN plume. The third objective was to monitor an enhanced bioremediation experiment, using carbon isotope ratios of TCE and its products to evaluate the extent of degradation.

APPROACH

We used measurements of hydrogen (δD) and oxygen ($\delta^{18}O$) isotope in waters, stable carbon ($\delta^{13}C$) and radiocarbon (^{14}C) in dissolved inorganic carbon compounds (DIC), the $^{87}Sr/^{86}Sr$ ratios of dissolved strontium, and the $\delta^{13}C$ values of chlorinated solvents. Hydrogen and oxygen isotope measurements can be used to identify subsurface water that has undergone extensive evaporation at the surface. Carbon isotope measurements of DIC and chlorinated solvents can be used to identify the results of biodegradation of organic materials. The $^{87}Sr/^{86}Sr$ ratios of dissolved strontium is used to determine the recharge area of groundwaters and as a monitor of dilution of the contaminant plume by ambient groundwater.

RESULTS

The $^{87}Sr/^{86}Sr$, $\delta^{18}O$, and δD data indicate that groundwaters in the TAN area have three sources. The water in the shallow aquifer containing the TCE plume comes from local infiltration of playa water derived ultimately from the Big Lost River. Water beneath the confining layer has two sources, that to the northeast is derived from Birch Creek, and that to the southwest has an unidentified source with lower $^{87}Sr/^{86}Sr$ (< 0.7096). The d18O values of the samples have a relatively large range of values (-15.3‰ to -18.5‰) that generally decrease from west to east. The $\delta^{18}O$ and δD values show a trend suggesting evaporation at low humidity, also indicating the playa as a source. The Sr isotope data also show that the low-$^{87}Sr/^{86}Sr$ waters from the southwestern source are upwelling through the confining layer in the same area where the highest $\delta^{18}O$ values are found. It may be the low-$^{87}Sr/^{86}Sr$ waters or the infiltrating playa waters that are responsible for redirecting groundwater flow eastward.

The TCE concentrations in the TAN plume decrease much more quickly than the strontium isotope ratios, which indicates that rapid degradation of TCE is occurring in the plume, but not by what mechanism. However, monitoring of the $\delta^{13}C$ compositions of TCE and the intermediary byproducts of reductive dechlorination during the enhanced bioremediation experiment confirmed that complete reductive dechlorination of the TCE was occurring.

SIGNIFICANCE OF FINDINGS

The results demonstrate that isotopic measurements can be used to help answer questions of critical importance for environmental management. Our studies show that natural biodegradation of chlorinated solvents can be documented by carbon isotope ratios and that engineered biodegradation can be verified by measurements of natural isotopic tracers. Natural isotopic tracers can be used in lieu of injection experiments for characterization of groundwater systems. The studies also produced basic field data applicable to understanding unsaturated zone hydrology and the potential for subsurface biologic activity in arid environments.

RELATED PUBLICATIONS

Conrad, M.E., A.S. Templeton, P.F. Daley and L. Alvarez-Cohen, Seasonally-induced fluctuations in microbial production and consumption of methane during bioremediation of aged sub-surface refinery contamination, Environ. Sci. Technol. 33, 4061-4068, 1999.

Johnson, T.M., and D.J. DePaolo, Interpretation of isotopic data in groundwater-rock systems: model development and application to Sr isotopic data from Yucca Mountain, Water Resources Res., v. 30, p.1571-1587, 1994.

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